MIT
International Center for
Air Transportation

Environmental Negotiation Frameworks for Multi-Stakeholder Air Transportation Systems

Joint University Program

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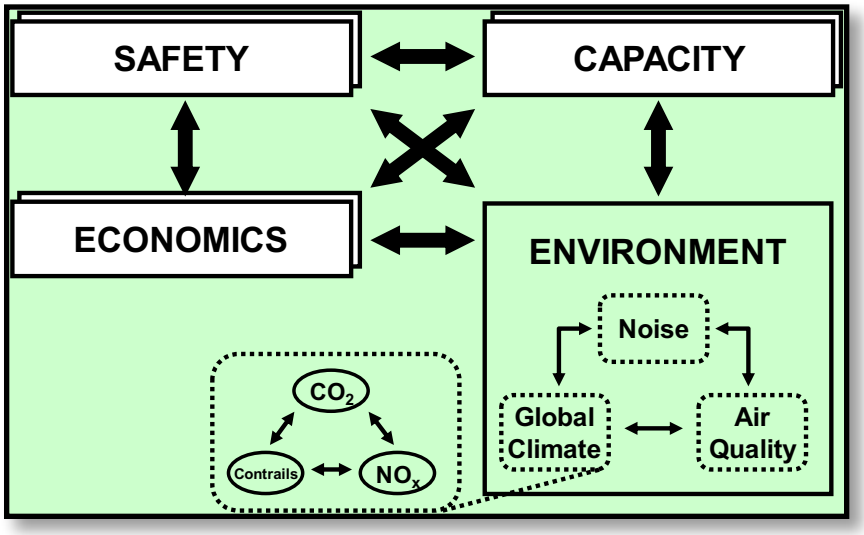
August 1, 2016

Motivation: System Design Tradeoffs

- Several important tradeoffs need to be considered for the design and optimization of air transportation systems
  - System objectives
    - Safety, cost, capacity
    - Environmental
  - Stakeholder valuation and prioritization
    - Monetized cost/benefit
    - Non-monetized welfare and equity
  - Consideration for disaggregate local and global costs and benefits



Accounting for Intangibles

- Air transportation environmental impact involves many **externalities**
  - Cost or benefit that affects a party who did not choose to incur that cost or benefit
- Disaggregate cost and benefit leads to **inequity**
- Emotional response, social welfare, and questions of appropriate timescale

- Potential solutions
  1. Evaluation away from Pareto frontier
  2. Democratic input processes
  3. Fast, transparent, and parametric modeling

Optimization and Negotiation in Environmental Problems

1) Key challenges of noise problem (and similar multi-stakeholder environmental impact problems):
   - No definitive formulation
   - No end point (stopping rule)
   - No enumerable set of solutions
   - "Wicked Problem" in optimization terminology
2) Such problems present challenges for typical optimization frameworks
   - What is the cost function?
     - Different for each stakeholder
     - Unknown, dependent, or stochastic to most stakeholders
   - Which stakeholder (or weighted-average of stakeholders) drives the optimizer?
3) Multi-stakeholder environmental tradeoff problems must be formulated as technical negotiations with mixed-fluency audiences

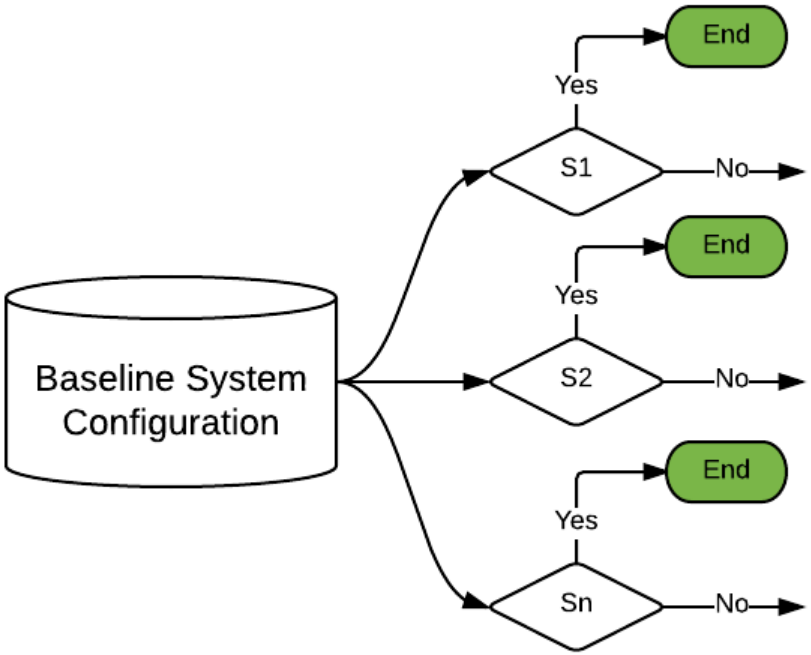
Problem Definition

- Several key challenges arise from an analysis standpoint:

1. Which variables should be considered?
2. Which stakeholders should be involved in the negotiation process?
3. How should information be presented and visualized for mixed-fluency stakeholders to effectively evaluate design trade spaces?

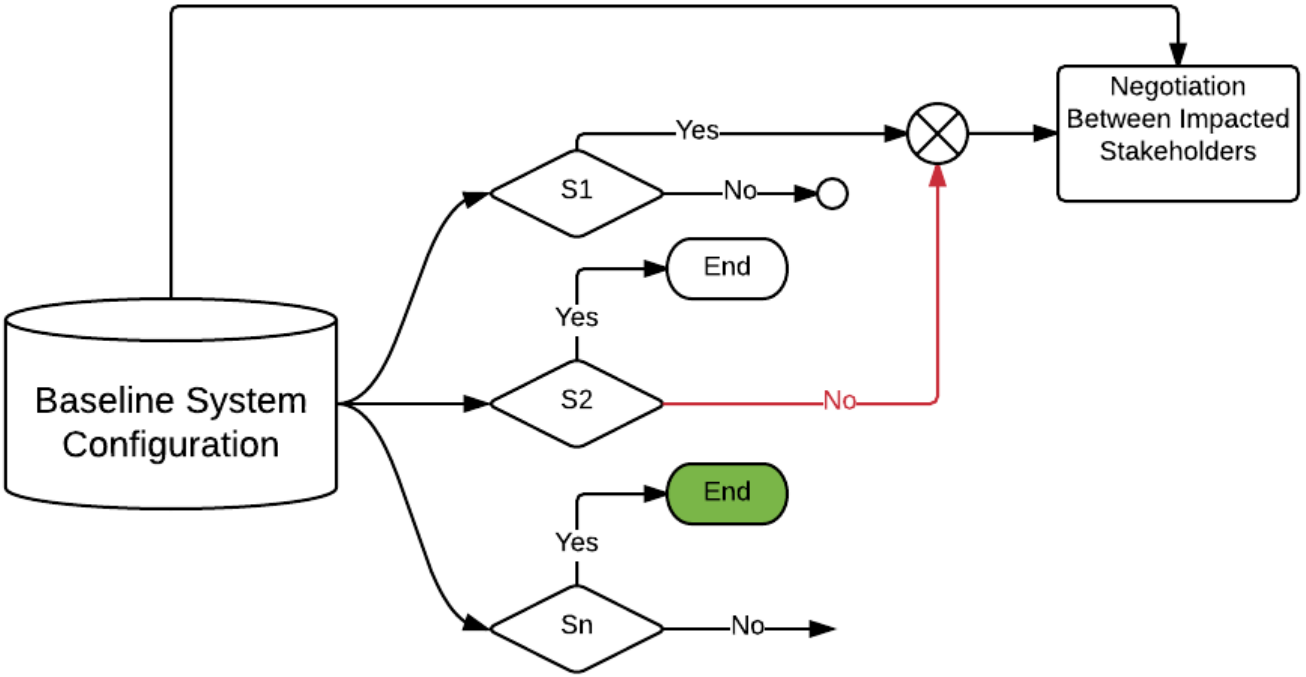
Architecture

- Baseline system configuration is presented to all stakeholders $\mathbf{S_n}$
- Under scenario where all stakeholders are in agreement with configuration, no further negotiation is necessary



Architecture

- Under scenario where one or more stakeholders is dissatisfied with status quo, negotiation (and potentially re-optimization) may be initiated
- Scenario:
  - S_1 proposes a system configuration change, triggering re-evaluation by all stakeholders
  - Proposed system configuration change not acceptable to S_2

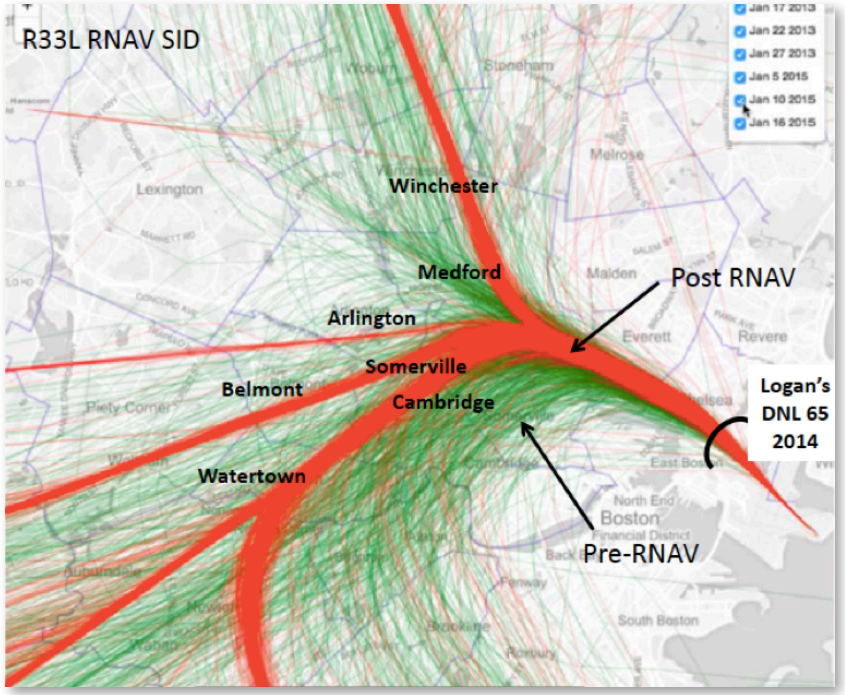


Negotiation Process

- Stakeholders involved with negotiation:
  - Proponent of system change
  - All stakeholders who do not approve of system change
  - Neutral (observer) stakeholders
- **Objective**: translate problem to technical negotiation using relevant metrics
- Identification of relevant negotiation metrics $\mathbf{M_n}$:
  - Metrics 1 through *m*: quantities of interest that motivated the proposed change (desirable outcomes for S_1)
  - Metrics *m*+1 through *n*: "pain point" quantities for opposing stakeholders (undesirable outcomes for S_2)
- Quantification and visualization of metrics M_1 through M_n becomes key component of negotiation
  - May be continuous or discrete

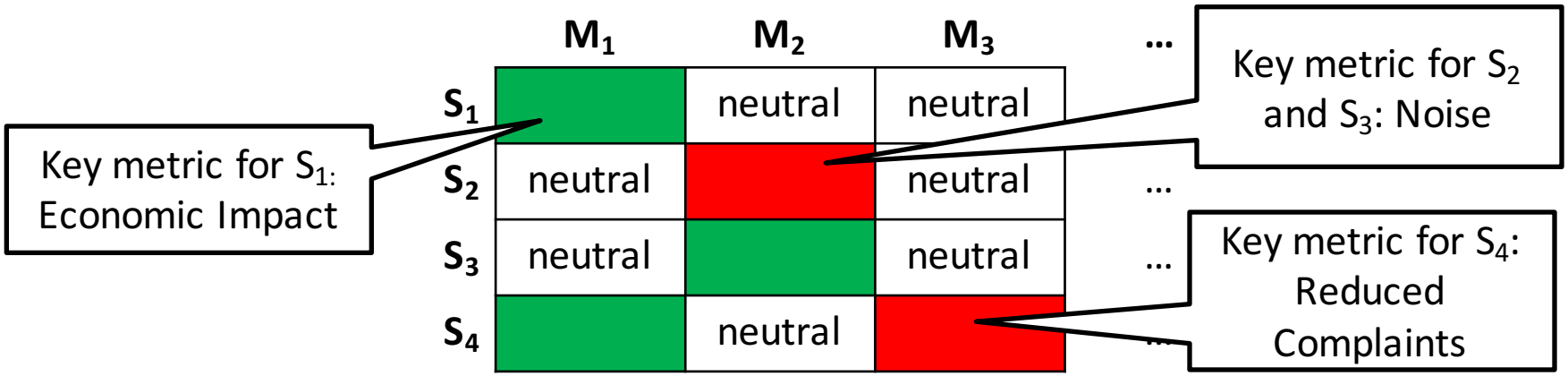
Noise Implications from PBN

- Flight track concentration has generated increased noise complaints
- Strong community and congressional pressure
  - Fundamental challenge for NextGen Implementation
- Current analysis tools may not capture potential benefits from RNAV/RNP implementation
  - Analysis to be conducted under ASCENT Project 44: Noise Reduction Analysis of Advanced Operational Procedures



Simple Case: Negotiation Matrices

- Impact matrix for policy with following stakeholders:
  - S_1: Airline that benefits from proposed change
  - S_2: Community member who opposes proposed change
  - S_3: Community member who supports proposed change
  - S_4: Airport operator (not directly incentivized to change)
- Impact matrix used to guide negotiation and consensus process
  - M_1: Notional economic/technical benefit to Airline S_1
  - M_2: Increased overflight frequency over neighborhood of S_2
  - M_3: Frequency of noise complaints to airport and politicians



Narrowed Negotiation Objectives

- High dimensionality of the problem is reduced by focusing only on key "pain point" variables
  - Best-case: benefit variable S_1 held constant (i.e. economic or throughput improvement for airlines), impact variables S_2 improved by moving to Pareto frontier
- Role of technical analyst:
  - Use set of discrete (i.e. runway use) or continuous (i.e. track dispersion or offset) techniques to reduce impact
  - Identifying feasible solutions on the Pareto frontier for variable P_1
  - Providing sensitivity estimates for impact variables P_n as benefits level is relaxed

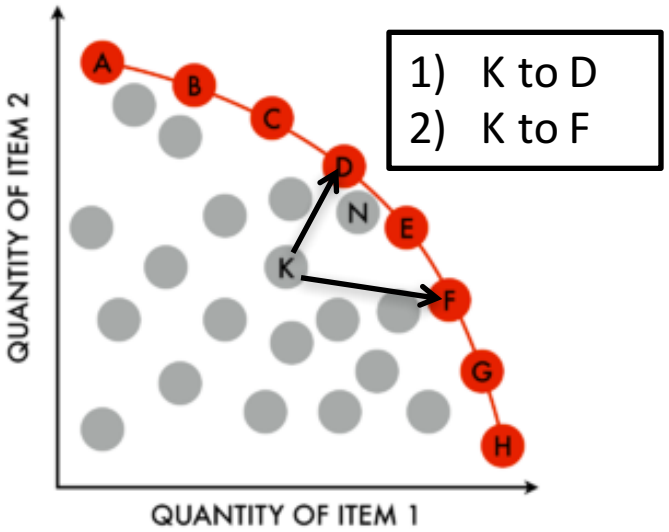
Selecting a Preferred Solution

1: Pareto efficiency:

- *Does a solution improve valuation for at least one stakeholder without reducing valuation for another?*

2: Kaldor-Hicks Criterion:

- *Does a solution improve valuation for all stakeholders taken together (net societal benefit)?*
- Cornerstone of traditional cost-benefit analysis
- Does not guarantee that all stakeholders realize benefit or compensation (inequitable)

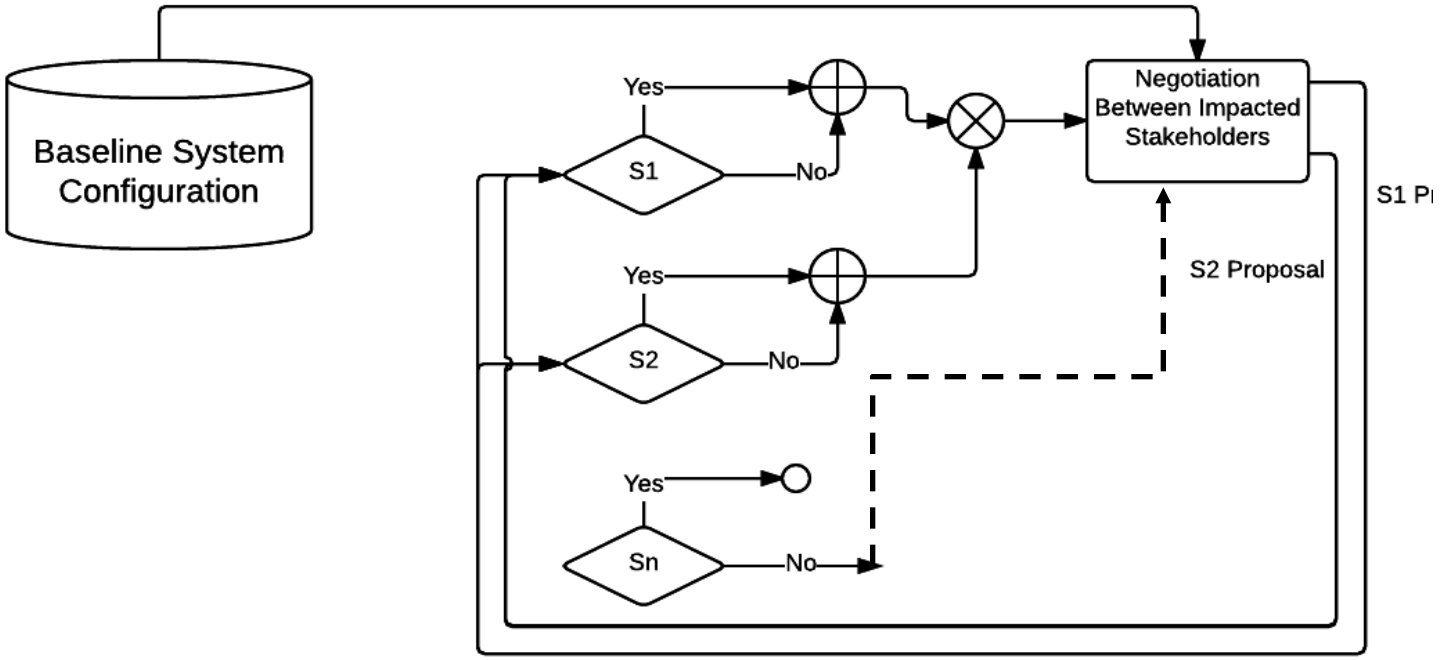


Notional valuation of two outcomes

Generalizes to n-dimensions

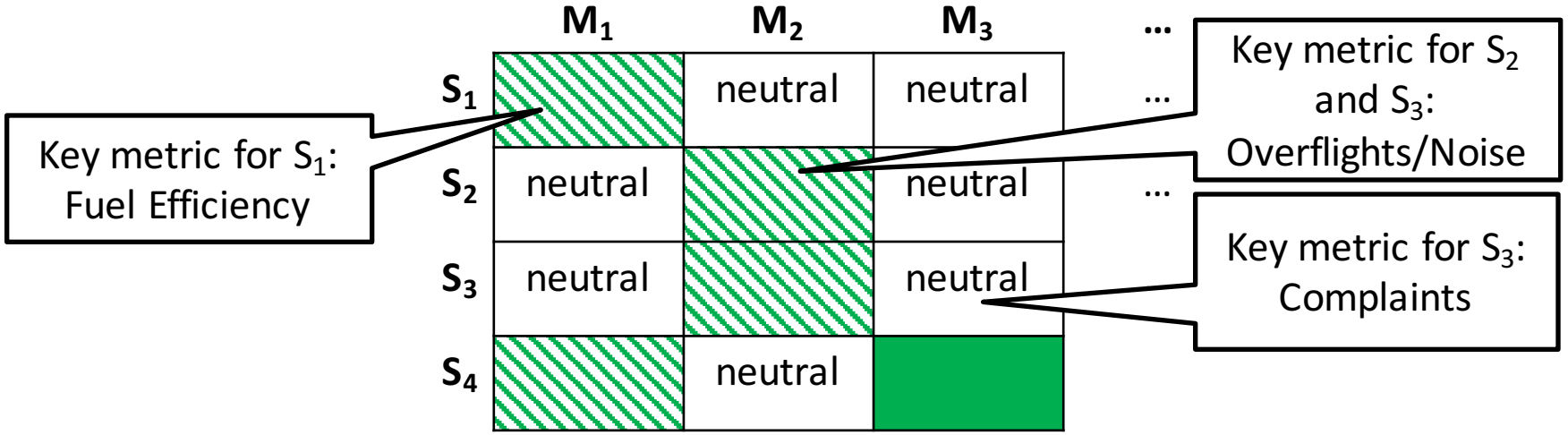
Negotiation Architecture

- S_1 and S_2 generate proposed changes accounting for sensitivity of all key parameters, re-submit for evaluation by other involved parties
- Process continues until S_1 and S_2 reach consensus on key variables
- All stakeholder have visibility over negotiation (and option to participate)



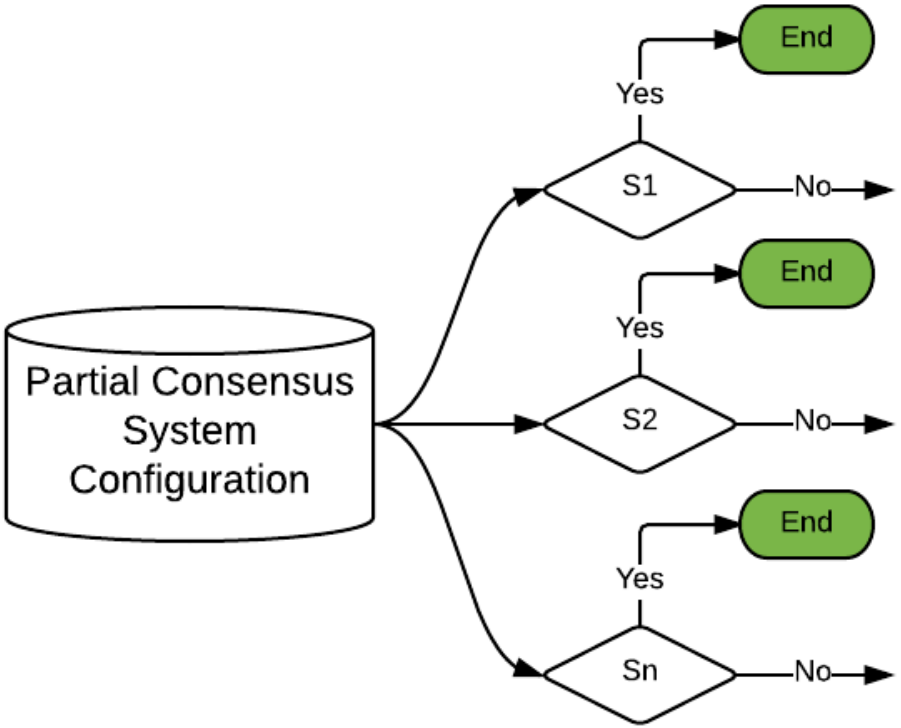
Negotiation Matrices

- Result: consensus solution for S_1 (airline) and S_2 (impacted community member)
  - Negotiated solution results in higher fuel burn, lower noise for S_2, higher noise for S_3
  - Consensus (perception of equity) reduces complaint rate for S_4
- Potential complications: higher noise for different community member S_4

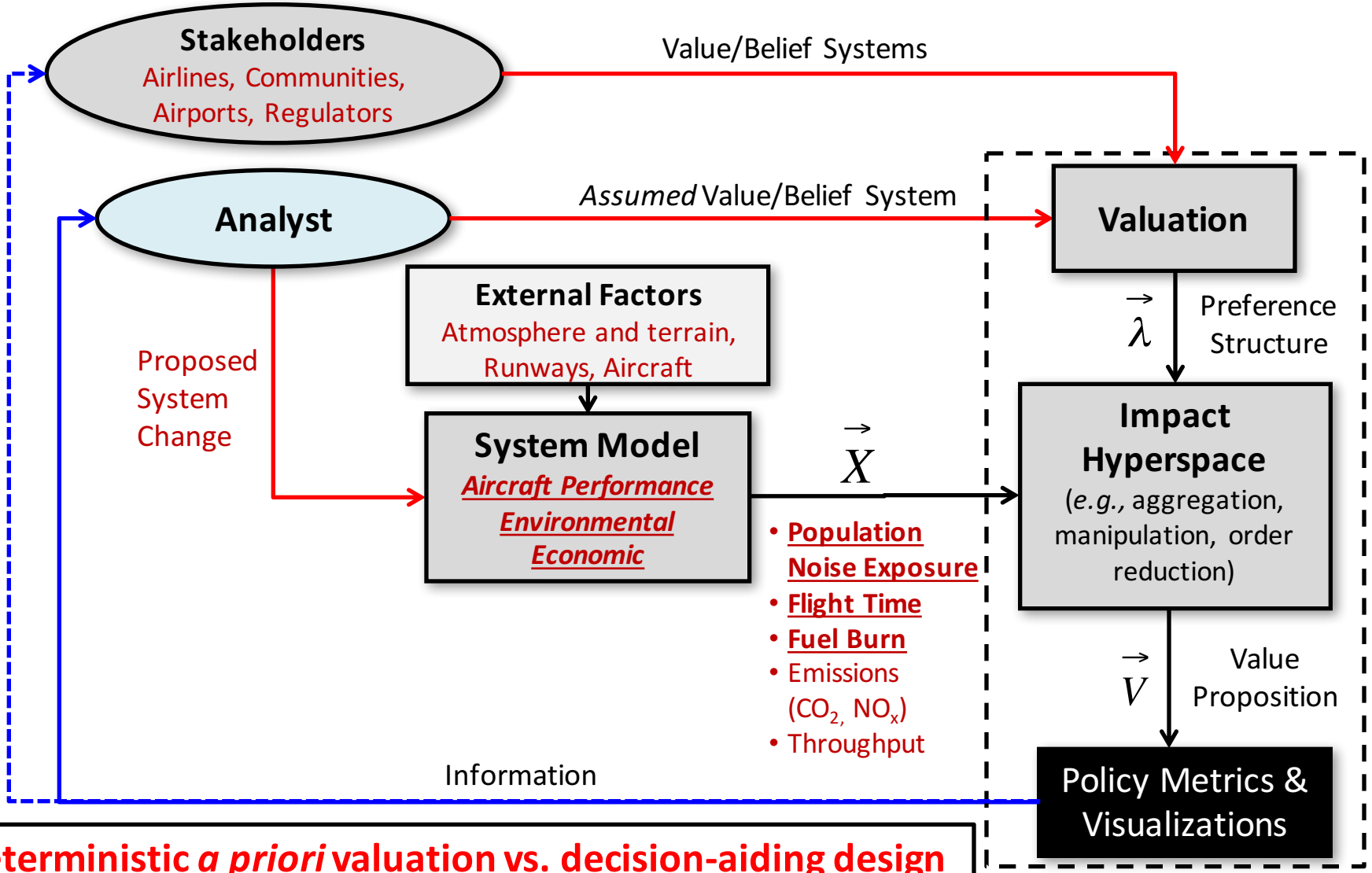


Negotiation Architecture: Multi-Stakeholder Evaluation

- Re-evaluate proposed solution with all stakeholders not involved with prior negotiation
- Dissenting stakeholders will trigger further evaluation or negotiation



Valuation Framework for Procedure Evaluation



Deterministic *a priori* valuation vs. decision-aiding design

Next Steps

- Develop graphical and data presentation formats to assist negotiation process in PBN procedure development
  - Baseline work underway to support rapid environmental modeling project
- Identify sample problem to demonstrate negotiation framework
  - Baseline configuration
  - Procedural objectives
- Generalize decision processes from PBN sample problem to air transportation environmental policy